JME 4110: Extended Hole Punch

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Extended Hole Punch

Lucas Mennemeier

Jason Zobrist

Joint Engineering Program

University of Missouri–St. Louis ▪ Washington University in St. Louis

ELEVATE YOUR FUTURE.
ELEVATE ST. LOUIS.

For this project we designed an extended hole punching tool that can reach the center of a standard piece of paper. Most hole punches on the market do not have a long throat and can only punch holes in the edges/corners of paper. The purpose of this design is to make a more useful hole punch with more applications than a standard hole punch.

JME 4110
Mechanical Engineering
Design Project

Hole Punch

Lucas Mennemeier
Jason Zobrist

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3. DESIGN AND DEVELOP A WORKING PROTOTYPE OF A SINGLE-HAND, SINGLE HOLE PUNCH WITH AN EXTENDED THROAT THAT WILL BE ABLE TO REACH FURTHER INTO A SHEET OF PAPER THAN A STANDARD SINGLE HOLE PUNCH. THIS CAN BE A PUNCH ATTACHMENT OR A STAND ALONE DEVICE. EITHER DESIGN CHOSEN WILL ALSO BE ABLE TO BE CONVERTED INTO AN EMBOSSING TOOL FOR EMBOSSING SEALS INTO DOCUMENTS.

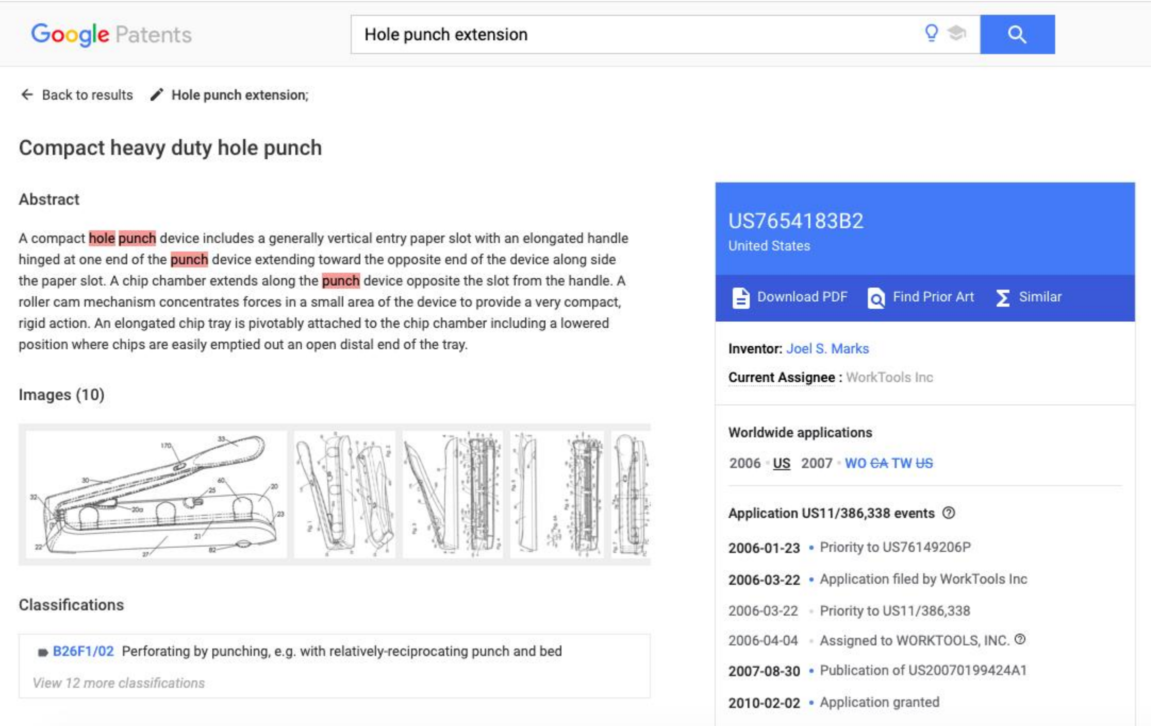
4. LUCAS MENNEMEIER & JASON ZOBRIST

2 BACKGROUND INFORMATION STUDY

5. DESIGN BRIEF

This design is for when you want to punch a hole further from the edge of the paper. The design will be a hole punch that reaches all the way to the center of a standard 8.5” x 11” sheet of paper.

6. BACKGROUND SUMMARY



https://patents.google.com/patent/US7654183B2/en?q=Hole+punch+extension&oq=Hole+punch+extension

Here is a hole punch patent found on google patents that fits closely to what we will be designing. Our design will need to include aspects of this design.

3 CONCEPT DESIGN AND SPECIFICATION

7. USER NEEDS AND METRICS

Needs Table for Extended Hole Punch

Need Number	Need	Importance (1-5)
1	Capacity same as standard punch (5 Sheets)	3
2	Standard Hole Size (¼”)	3
3	Lightweight design	3
4	Embossing tool	2
5	1.5”1.5 embossing seal tooling	2
6	Tool Reach (4.25”)	5
7	Low Grip Force	3
8	Comfort Grips (Soft Grips)	3
9	One handed Operation (Non Table Top)	5
10	Design as an add-on attachment	2
11	Cost compared to standard hole punch (2 to 3X standard)	4
12	Destroyer of Mail	4

3.1.1 Record of the user needs interview

Hole Punch Interview

6/28/21
Interviewers: Jason Zobrist, Lucas Mennemeier
Interviewees: Mark Jakiela, Craig Giesmann

1. What specifications of a standard hole punch such as capacity, hole size and design are needed in an extended hole punch.
    a. Same size hole, adjustable (3)
2. What is the required reach of the extended hole punch? Center of 8.5" x 11"?
    a. 4.25" deep max (5)
3. How important is ergonomics and design? Lightweight? Comfort Grips? Color? Style?
    a. Possible new hole die
4. Is it desired to be a one handed off the table design?
    a. Yes (5)
5. Grip force similar to standard hole punch or is lower force needed?
    a. As high as a standard hole punch (130%) (4)
6. Is cost important compared to a standard hole punch?
    a. No more than original punch (if extension) (3)
    b. 2 -3 times as expensive as standard (if standalone)
7. Is there a standard size embossing tool that is needed?
    a. 1.5" diameter embossing tool (2)

3.1.2 List of identified metrics

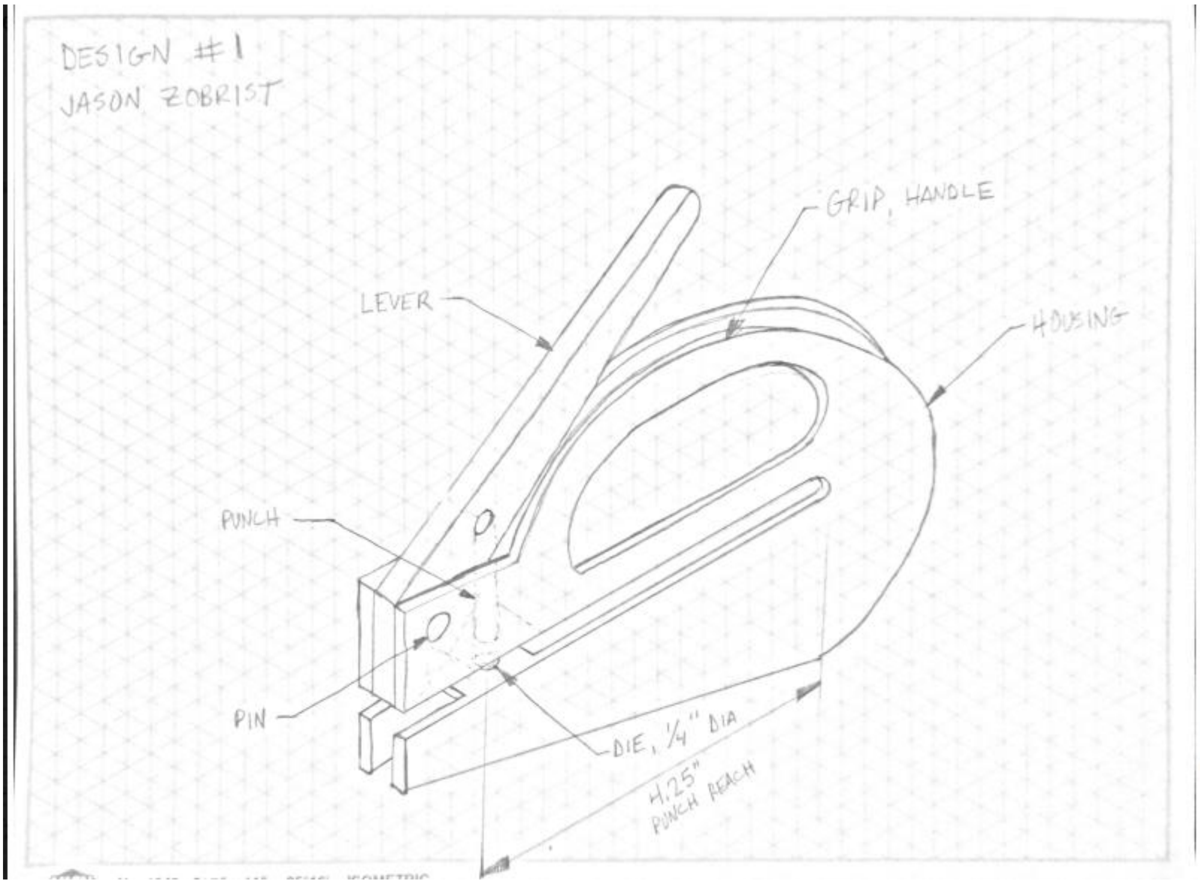
Metrics Table for Extended Hole Punch

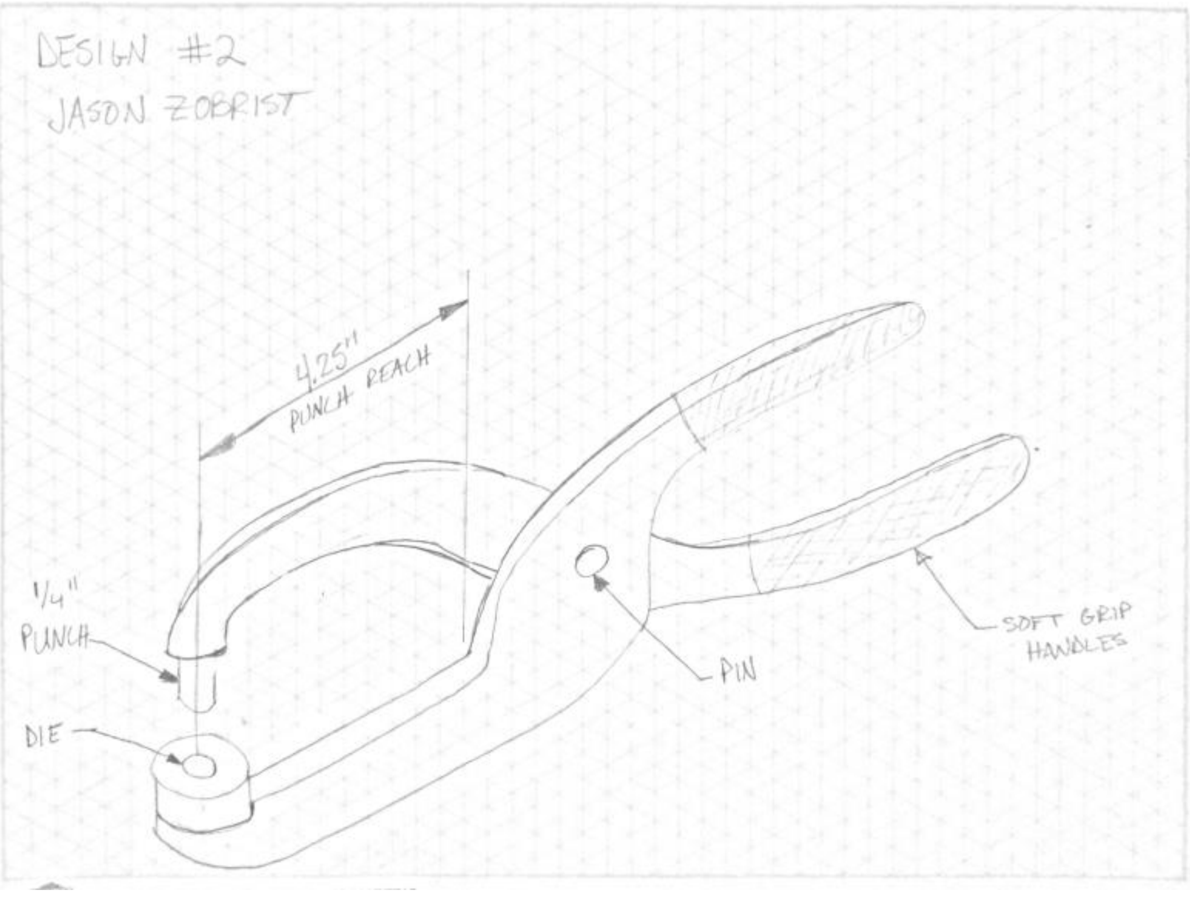
Metric Number	Associated Needs	Metric	Units	Min Value	Max Value
1	12	Length	in	6	10
2	2	Punch Diameter	in	3/16	5/16
3	3	Weight	oz	2	16
4	2,8	Number of sharp edges	Integer	1	3
5	7	Grip Force	lbs	x	x
6	11	Cost	US Dollars	5	15
7	1	Capacity	Paper Sheets	1	20
8	6,12	Tool Reach	in	4.25	5
9	4	Emboss Tool Size	in	1	1.5
10	8	Comfort Grips	Integer	0	2

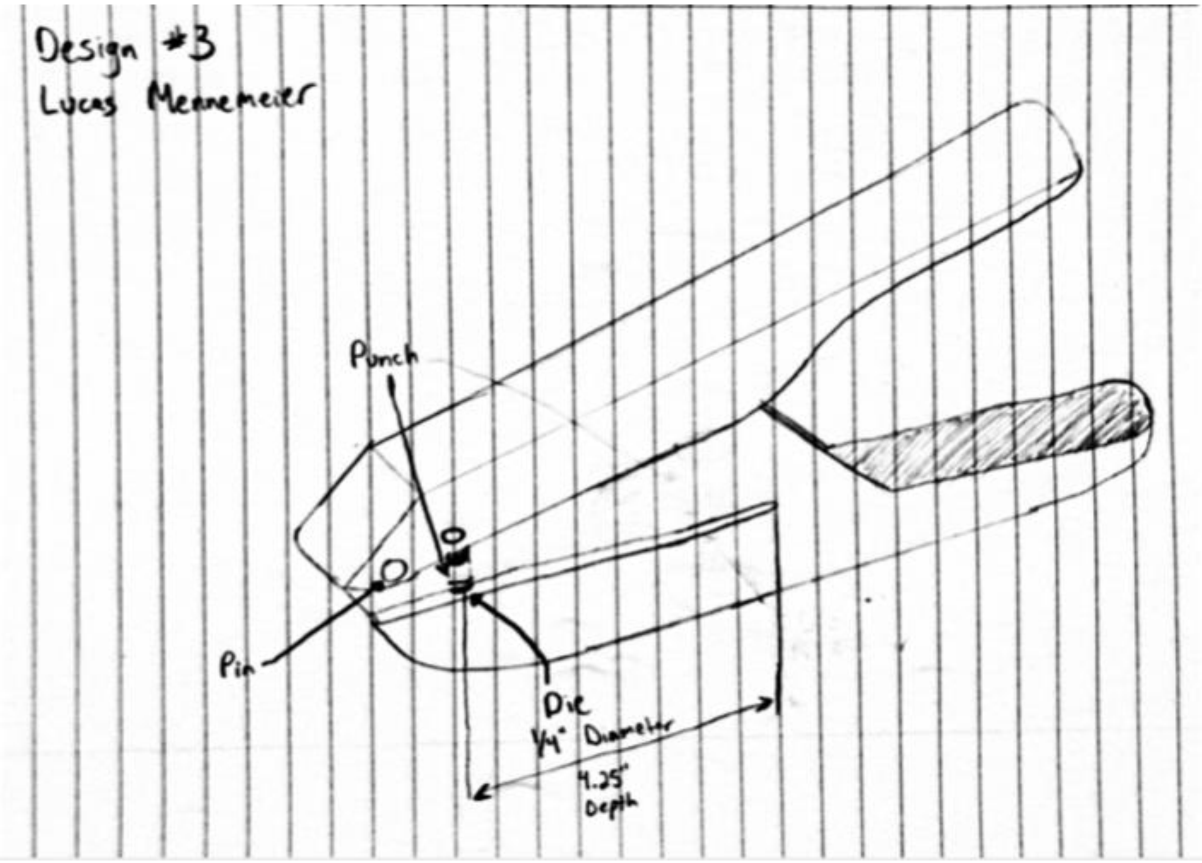
3.1.3 Table/list of quantified needs equations

Punch Tool (Design #2)		Metric															
		Length	Punch Diameter	Weight	# of Sharp Edges	Grip Force	Cost	Capacity	Tool Reach	Emboss Tool Size	Comfort Grips	Manufacturing Ranking	-	-	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Capacity same as std hole punch	0.1	0.2		0.2	0.2			0.2		0.1				0.466	0.1	0.047
2	Standard hole size		1												0.496	0.075	0.037
3	Lightweight	0.2		0.2				0.3	0.2		0.1				0.249	0.05	0.012
4	Embossing tool Attachment									1					1.000	0.025	0.025
5	1.5" Embossing tool size			0.1						0.9					0.943	0.025	0.024
6	4.25" Min. Tool Reach	0.2							0.8						0.000	0.2	0.000
7	Low Grip Force	0.5							0.5						0.000	0.05	0.000
8	Comfort Grips										1				1.000	0.025	0.025
9	One handed off table operation	0.5		0.5											0.214	0.05	0.011
10	Design as add on attachment						1								1.000	0.05	0.050
11	Cost less than 3x of standard						1								1.000	0.05	0.050
12	Ease of Manufacturing						0.2					0.8			1.000	0.2	0.200
13	Destroyer of Mail				1										1.000	0.1	0.100
Units		in	in	oz	Integer	lbs	US Dollar	Sheets	in	in	Integer	-	-	-	Total Happiness		0.581
Best Value		6	0.313	2	1	0	5	20	5	1.5	2	10					
Worst Value		10	0.188	16	3	15	45	1	4.25	1	0	1					
Actual Value		10	0.25	10	1	10	5	5	4.25	1.5	2	10					
Normalized Metric Happiness		0.000	0.496	0.429	1.000	0.333	1.000	0.211	0.000	1.000	1.000	1.000					

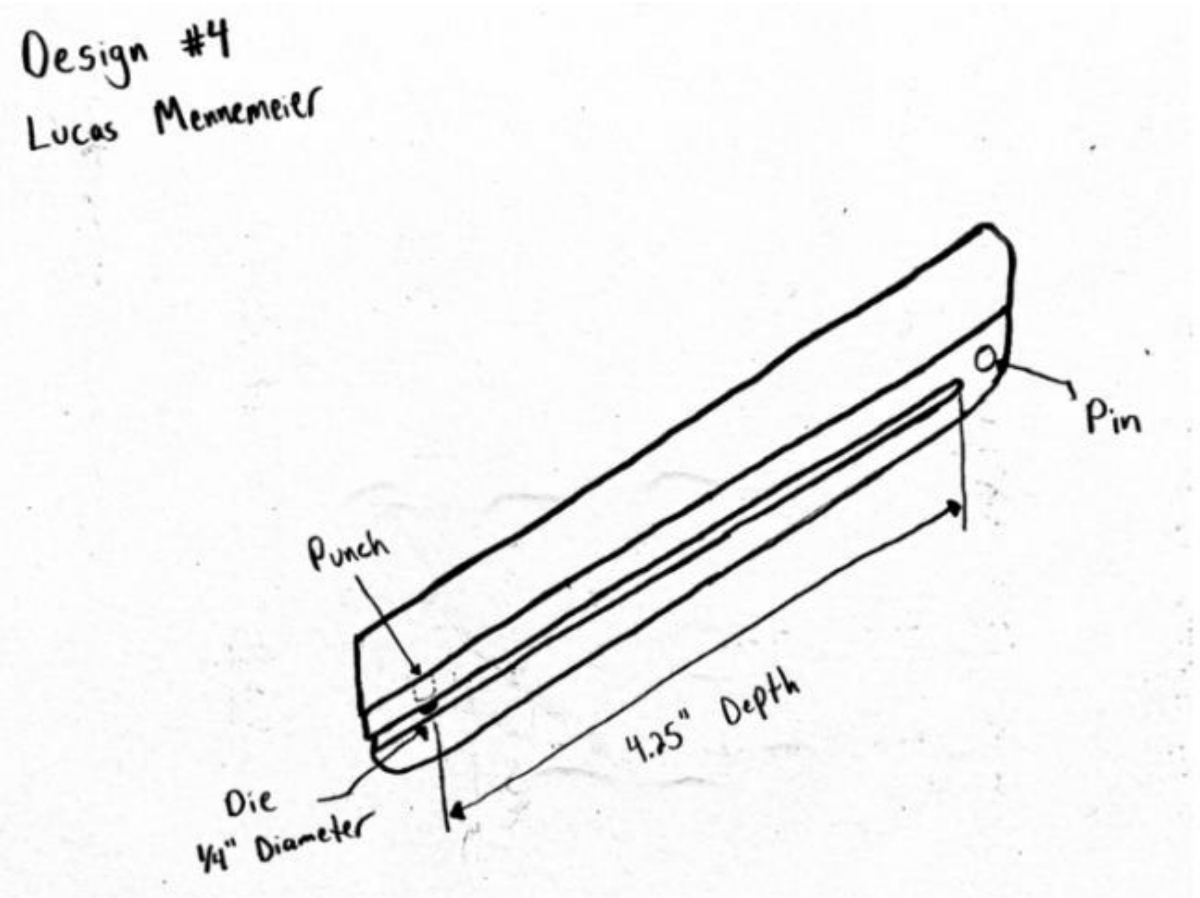
8. CONCEPT DRAWINGS







Design #3
Lucas Mennemeier
Punch
Pin
Die
1/4" Diameter
4.25"
Depth



Design #4
Lucas Mennemeier
Pin
Punch
4.25" Depth
Die
1/4" Diameter

9. A CONCEPT SELECTION PROCESS.

3.1.4 Concept scoring (not screening)

Metrics table happiness scores:

Design 1: 0.558

Design 2: 0.581

Design 3: 0.447

Design 4: 0.485

3.1.5 Preliminary analysis of each concept's physical feasibility

Design #1

This design seems to be physically feasible. It is a somewhat robust design with grip and lever positioning that would make the goal of punching holes in sheets of paper possible. To make the design lightweight like standard hole punches, the materials used would most likely need to be lightweight. For example, we would probably not want to use steel for the housing, but rather a lighter material such as aluminum or maybe plastic.

Design #2

The second design concept also seems physically feasible. This design is not as robust as design #1, so the need for lightweight materials is not as important. It is a simpler design that would require fewer parts which is desirable. The relatively thin arms that hold the punch and the die will need to be made of a strong material to prevent deflection caused by the force applied during punching.

Design #3

This design also seems physically feasible. It is a bit more robust than design #2 so lightweight materials would need to be considered. The length of the handles present the possibility of deflection when attempting to punch through multiple sheets of paper, so a strong material would need to be used for these.

Design #4

It is debatable if this design is physically feasible. This design differs greatly from the previous 3, as it looks more like a stapler. This design may require special help to produce the necessary force to punch through multiple sheets of paper based on the way it would need to be gripped by the user. It could potentially work as a table top hole punch, but we are looking for a handheld device.

3.1.6 Final summary statement

We came up with four design concepts for our extended single hole punch product.

These four concepts were compared using our metrics table that we made including our user needs and metrics. The design that scored the highest was design #2 and this is the concept that we are choosing to continue with. We first determined which of the design concepts would work for our desired goal and quickly determined that design #4 would most likely not work. The way the user would need to hold the device would not allow them to apply the force necessary to punch through multiple sheets of paper, so this concept was discarded. Designs 1-3 all seem to be feasible and would be able to accomplish our goal so we needed to use other criteria to pick a winner. From what we could determine, designs 1-3 performed similarly in most of the metrics, but what stood out to us was the ease of manufacturing for design #2. Designs #1 and #3 are more robust and would require more complex parts to manufacture, which also increases the cost of manufacturing. The simplicity of design #2 is what sets it apart from #1 and #3, as it is just two curved components connected with a pin. We felt that the design's simplicity will make it the cheapest and easiest to manufacture while still meeting the user's needs.

10. PROPOSED PERFORMANCE MEASURES FOR THE DESIGN

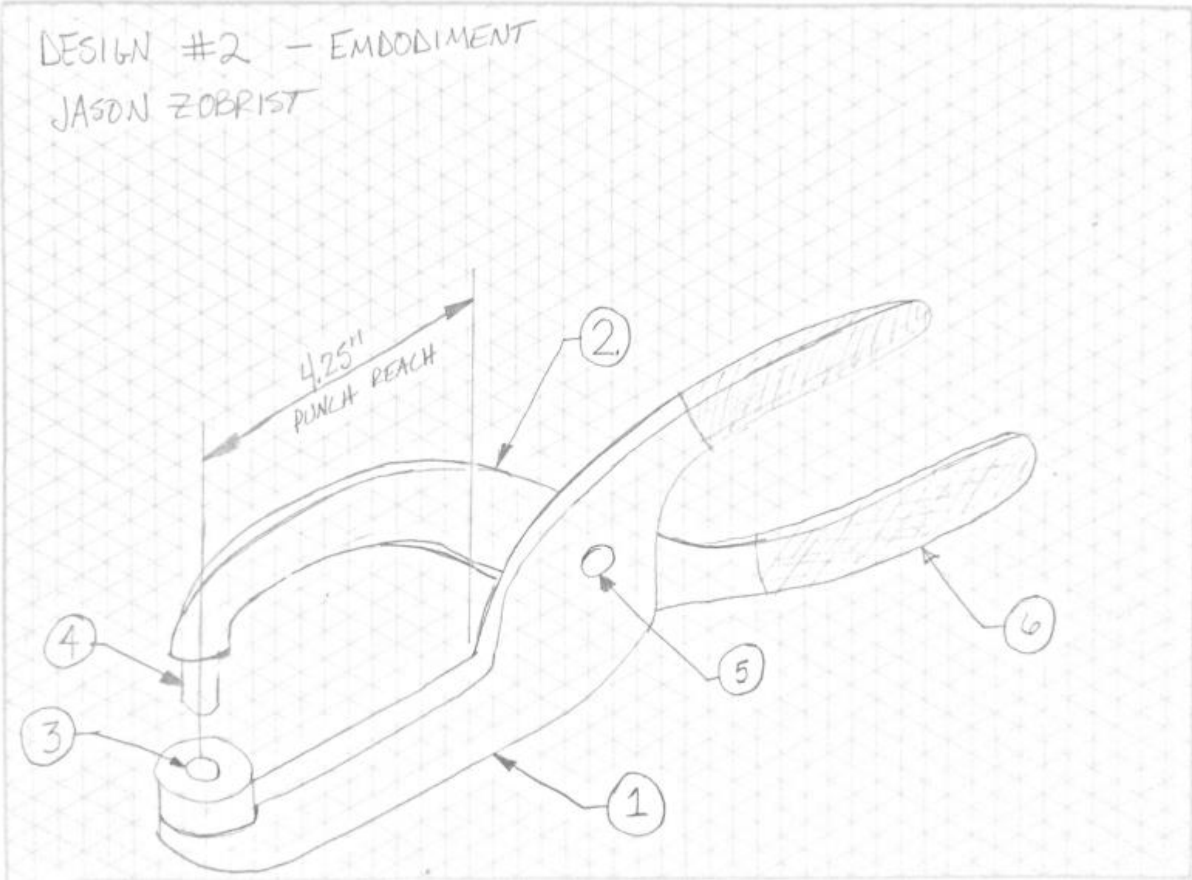
The user need we identified as the overall performance measure is that the hole punch can reach the center of a standard 8.5” x 11” sheet of paper. We feel this is the most important need considering the point of the project is to design an extended hole punch.

11. REVISION OF SPECIFICATIONS AFTER CONCEPT SELECTION

No revisions of specifications were necessary after concept selection.

4 EMBODIMENT AND FABRICATION PLAN

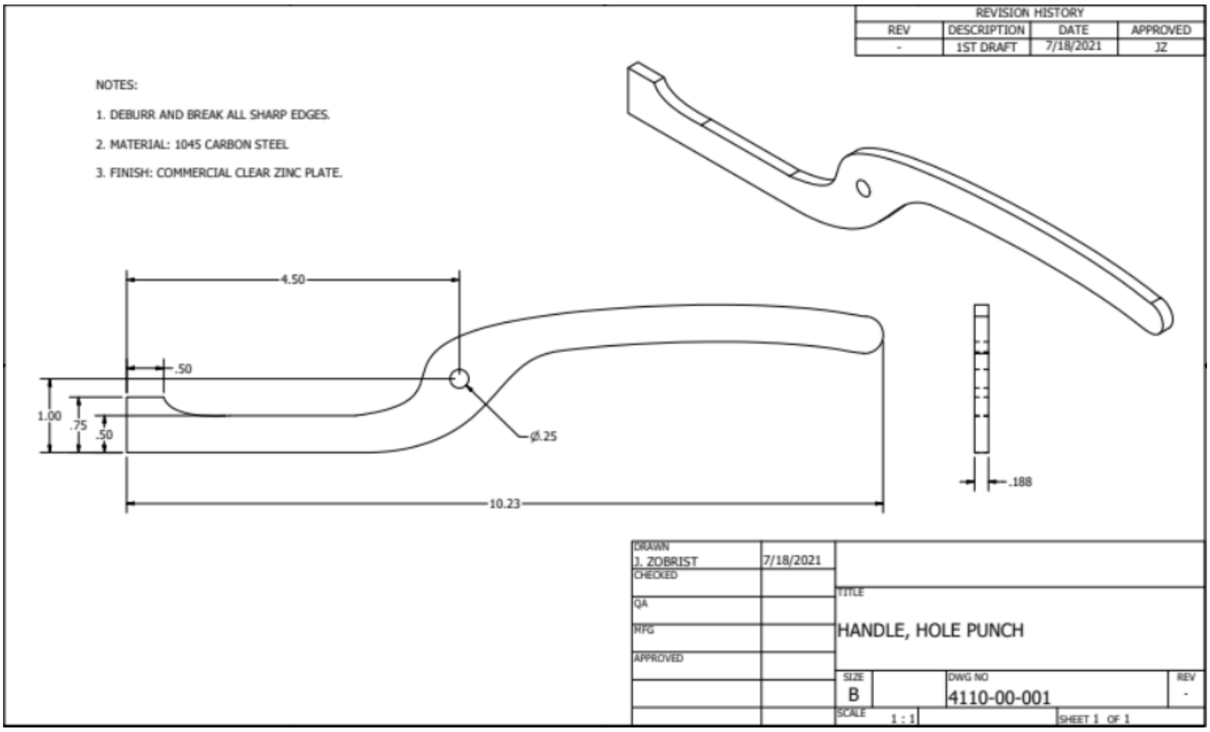
12. EMBODIMENT/ASSEMBLY DRAWING

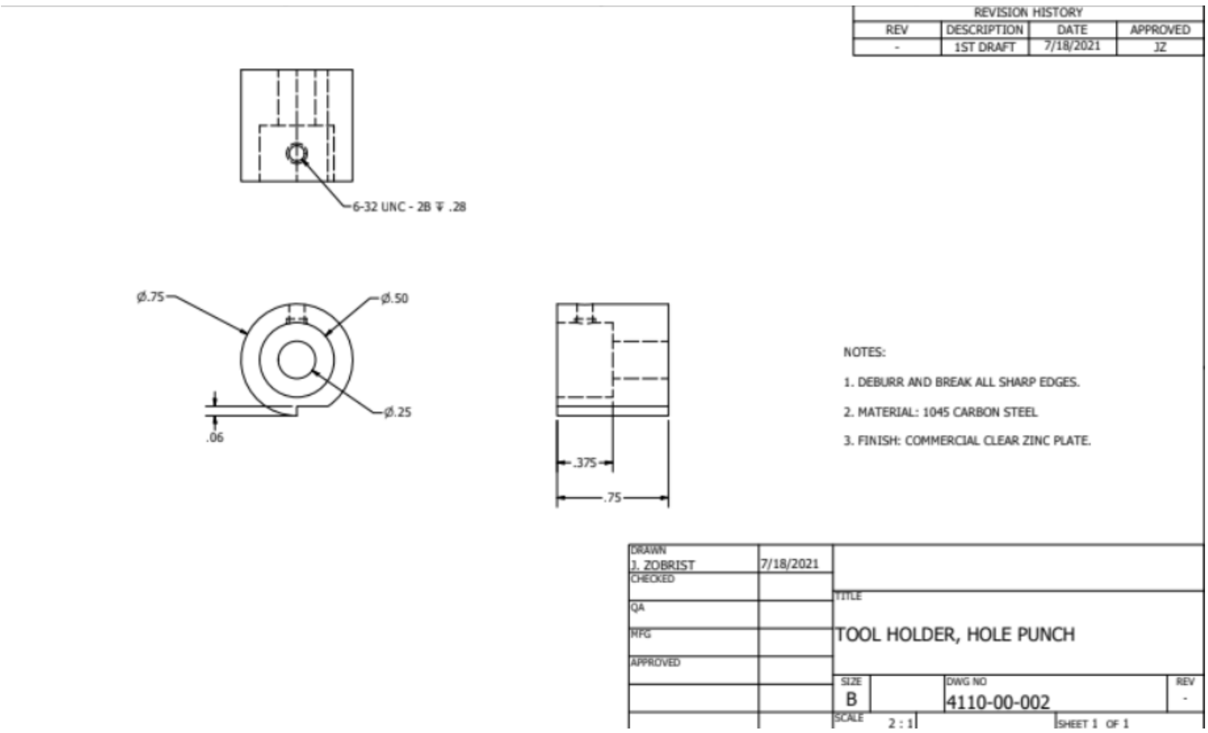


13. PARTS LIST

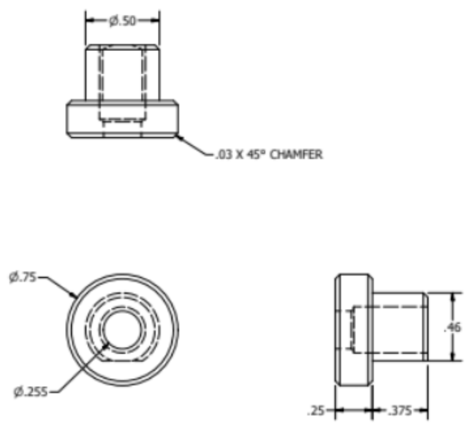
Die Handle
Punch Handle
Die Material
Punch Material
Binding Pin
Grips

14. DRAFT DETAIL DRAWINGS FOR EACH MANUFACTURED PART





REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED
-	1ST DRAFT	7/18/2021	JZ

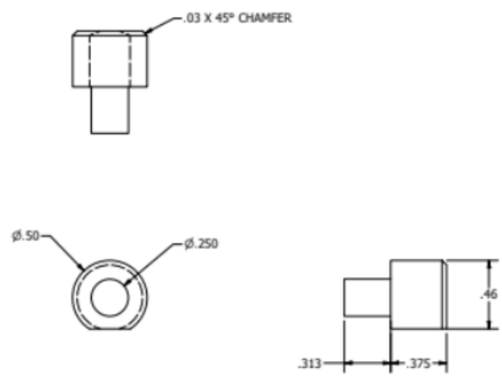


NOTES:

1. DEBURR AND BREAK ALL SHARP EDGES.
2. MATERIAL: TOOL STEEL
3. FINISH: COMMERCIAL CLEAR ZINC PLATE.

DRAWN J. ZOBRIST	7/18/2021			
CHECKED		TITLE		
QA		DIE, HOLE PUNCH		
MFG				
APPROVED				
		SIZE B	DWG NO 4110-00-003	REV -
		SCALE 2 : 1		SHEET 1 OF 1

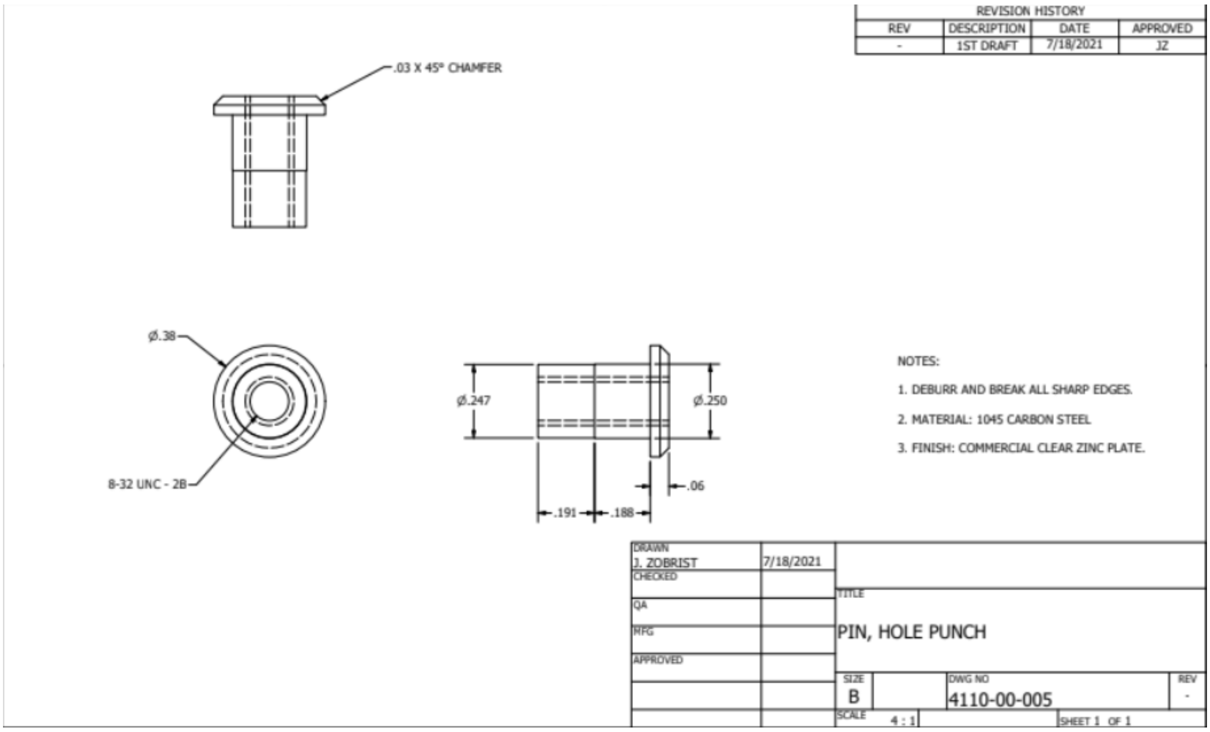
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED
-	1ST DRAFT	7/18/2021	JZ



NOTES:

1. DEBURR AND BREAK ALL SHARP EDGES.
2. MATERIAL: TOOL STEEL
3. FINISH: COMMERCIAL CLEAR ZINC PLATE.

DRAWN J. ZOBRIST	7/18/2021			
CHECKED		TITLE		
QA		PUNCH, HOLE PUNCH		
MFG				
APPROVED				
		SIZE B	DWG NO 4110-00-004	REV -
		SCALE 2 : 1		SHEET 1 OF 1



15. DESCRIPTION OF THE DESIGN RATIONALE

Overall Design: The overall design of the hole punch was made to be as compact as possible while trying to achieve as close to a 1:1 ratio between the handle and punch portions of the assembly. Grips were added to the handle for comfortability of the user. The handles were designed to be approximately 2 inches apart in the closed position so that they can be gripped easily. The handles are also arched so that they will fit the hand of the user similarly to a pair of pliers.

Handle: The material we will use for the handle of the hole punch is 1045 Carbon steel. This material was chosen because of its strength and its manufacturability. The handle is also designed to be symmetrical so that the same piece can be used for both handles.

Necessary Analysis: We will need to analyze the tolerance for interference/press fit for the pin and the pin hole so that the handles will be held together securely, but can also easily rotate around the pin. We may also consider a transition fit for this part of the assembly.

Tool Holder: The material we will use for the tool holder part of our prototype is 1045 carbon steel. This material was chosen because of its strength and manufacturability. This part is also designed to be symmetrical so that it can be used for both the punch and die sides of the prototype. A hole will need to be threaded for set screws that will hold the tools in place. This is so that different sized dies/punches can be inserted to make a variety of holes with different diameters if desired. The tool holder could also potentially accommodate future stamping tools.

Necessary Analysis: We will need to analyze the tolerance for transition fit of tool inserts and tool holders.

Die: The material used for the die will be tool steel. Tool steel was chosen for this part so that it can keep a sharp edge.

> **Necessary Analysis:** We will need to analyze the tolerance for transition fit of tool inserts and tool holders. We will also need to analyze the tolerance of clearance between die and punch tools.

Punch: The material used for the punch is also tool steel. Tool steel was also chosen for this part to keep a sharp edge.

> **Necessary Analysis:** We will need to analyze the tolerance for transition fit of tool inserts and tool holders. We will also need to analyze the tolerance of clearance between die and punch tools.

Pin: The material used for the pin to hold the handles together is 1045 carbon steel. This material was chosen for its strength and manufacturability. The pin will need to be press fit into one handle and transition fit into the other handle. The hole will need to be threaded for a screw to hold the handles together.

> **Necessary Analysis:** We will need to analyze the tolerance for the fits between the pin and the pin hole. We will also need to calculate the shear stress that the pin will be exposed to to ensure we use a pin with a high enough shear strength for this application.

5 ENGINEERING ANALYSIS

16. ENGINEERING ANALYSIS PROPOSAL

5.1.1 Signed engineering analysis contract

The following engineering analysis tasks will be performed:

1. We will need to analyze the press fit tolerance for the pin and the pin hole. This will be done by using tables from the Machinery's Handbook to choose proper clearan for the fit between components.
2. We will need to analyze the tolerance for transition fit of tool inserts and tool holders. This analysis will be done by using the Machinery's Handbook to choose prop clearances for the fit between components.
3. We will need to analyze the tolerance of clearance between die and punch tools This will most likely be completed through research of clearance between mating parts
4. We will need to calculate the shear stress that the pin will be exposed to to ensu we use a pin with a high enough shear strength for this application. This will be done through shear stress calculations.
5. We will need to analyze the necessary grip force required to punch through our goal of 5 sheets of paper using our prototype. This will be performed using engineering calculations and the standard shear strength of a standard sheet of paper.
6. We will need to analyze how much force will cause the arms of the hole punch yield. This will be done using finite analysis in Solidworks.

The work will be divided among the group members in the following way:
Jason : 1, 2, 3, & 6 **JZ**
Lucas: 4 & 5 **LM**

Instructor signature: Craig J. Giesmann; Print instructor name: _Craig J. Giesman
Instructor signature: Mark Jakiela; Print instructor name: _ Mark Jakiela

1. (Group members should initial near their name above.)

17. ENGINEERING ANALYSIS RESULTS

5.1.2 Motivation

We will need to analyze the press fit tolerance for the pin and the pin hole. This will be done by using tables from the Machinery's Handbook to choose proper clearances for the fit between components. This is important to analyze so that our handles will fit together properly, allowing one handle to rotate around the pin. If the fitting is too loose, displacement might occur during use that would throw off the location of the punch relative to the die that may interfere with the functionality of the design. Analyzing this fitting will help us determine what size our pin needs to be.

We will need to analyze the tolerance for transition fit of tool inserts and tool holders. This analysis will be done by using the Machinery's Handbook to choose proper clearances for the fit between components. This part is important to analyze so that our tooling will fit properly into the tool holders on the design. If the punch and die do not fit into their respective spots properly it will render the design useless.

We will need to analyze the tolerance of clearance between die and punch tools. This will most likely be completed through research of clearance between mating parts. This is important to include in our analysis so that we can determine the diameter of the hole required for the die. If we want our punch tool to punch a hole with ¼" diameter, it is important to know how much clearance we need to allow for the punch to pass through the die.

We will need to calculate the shear stress that the pin will be exposed to to ensure we use a pin with a high enough shear strength for this application. This will be done through shear stress calculations. This is important to include in our analysis so that we can avoid using a pin that is too small to withstand the shear stress applied by the user's grip force. These calculations will be made to help us select a pin that is strong enough to not deflect when subjected to the stresses applied during use.

We will need to analyze the necessary grip force required to punch through our goal of 5 sheets of paper using our prototype. This will be performed using engineering calculations and the standard shear strength of a standard sheet of paper. This is important to include in our engineering analysis because our hole punch will be useless if it requires an unrealistic grip force to punch through 5 sheets of paper. This analysis will help us confirm that our design will achieve our goal.

We will need to analyze how much force will cause the arms of the hole punch to yield. This will be done using finite element analysis in Solidworks. It is important to analyze this to determine whether our design is robust enough to withstand the stresses it will be subjected to during use. Our design will fail if the handles yield from the required force applied to punch through 5 sheets of paper.

5.1.3 Summary statement of analysis done

Tolerance Analysis for the pin and the pin hole

Fit Chosen: FN 2 *Medium drive fits* are suitable for ordinary steel parts, or for shrink fits on light sections.They are about the tightest fits that can be used with high-grade cast-iron external members.

Hole: .2506/.2500

Pin (Shaft): .2514/.2510

Table 9. ANSI Standard Force and Shrink Fits *ANSI B4.1-1967 (R1987)*

Nominal Size Range, Inches	Class FN 1			Class FN 2			Class FN 3			Class FN 4			Class FN 5		
	Inter-ference[a]	Standard Tolerance Limits		Inter-ference[a]	Standard Tolerance Limits		Inter-ference[a]	Standard Tolerance Limits		Inter-ference[a]	Standard Tolerance Limits		Inter-ference[a]	Standard Tolerance Limits	
Over To		Hole H6	Shaft		Hole H7	Shaft s6		Hole H7	Shaft t6		Hole H7	Shaft u6		Hole H8	Shaft x7
	Values shown below are in thousandths of an inch														
0– 0.12	0.05 0.5	+0.25 0	+0.5 +0.3	0.2 0.85	+0.4 0	+0.85 +0.6				0.3 0.95	+0.4 0	+0.95 +0.7	0.3 1.3	+0.6 0	+1.3 +0.9
0.12– 0.24	0.1 0.6	+0.3 0	+0.6 +0.4	0.2 1.0	+0.5 0	+1.0 +0.7				0.4 1.2	+0.5 0	+1.2 +0.9	0.5 1.7	+0.7 0	+1.7 +1.2
0.24– 0.40	0.1 0.75	+0.4 0	+0.75 +0.5	0.4 1.4	+0.6 0	+1.4 +1.0				0.6 1.6	+0.6 0	+1.6 +1.2	0.5 2.0	+0.9 0	+2.0 +1.4
0.40– 0.56	0.1 0.8	+0.4 0	+0.8 +0.5	0.5 1.6	+0.7 0	+1.6 +1.2				0.7 1.8	+0.7 0	+1.8 +1.4	0.6 2.3	+1.0 0	+2.3 +1.6
0.56– 0.71	0.2 0.9	+0.4 0	+0.9 +0.6	0.5 1.6	+0.7 0	+1.6 +1.2				0.7 1.8	+0.7 0	+1.8 +1.4	0.8 2.5	+1.0 0	+2.5 +1.8
0.71– 0.95	0.2 1.1	+0.5 0	+1.1 +0.7	0.6 1.9	+0.8 0	+1.9 +1.4				0.8 2.1	+0.8 0	+2.1 +1.6	1.0 3.0	+1.2 0	+3.0 +2.2
0.95– 1.19	0.3 1.2	+0.5 0	+1.2 +0.8	0.6 1.9	+0.8 0	+1.9 +1.4	0.8 2.1	+0.8 0	+2.1 +1.6	+1.0 2.3	+0.8 0	+2.3 +1.8	1.3 3.3	+1.2 0	+3.3 +2.5
1.19– 1.58	0.3 1.3	+0.6 0	+1.3 +0.9	0.8 2.4	+1.0 0	+2.4 +1.8	1.0 2.6	+1.0 0	+2.6 +2.0	1.5 3.1	+1.0 0	+3.1 +2.5	1.4 4.0	+1.6 0	+4.0 +3.0
1.58– 1.97	0.4 1.4	+0.6 0	+1.4 +1.0	0.8 2.4	+1.0 0	+2.4 +1.8	1.2 2.8	+1.0 0	+2.8 +2.2	1.8 3.4	+1.0 0	+3.4 +2.8	2.4 5.0	+1.6 0	+5.0 +4.0
1.97– 2.56	0.6 1.8	+0.7 0	+1.8 +1.3	0.8 2.7	+1.2 0	+2.7 +2.0	1.3 3.2	+1.2 0	+3.2 +2.5	2.3 4.2	+1.2 0	+4.2 +3.5	3.2 6.2	+1.8 0	+6.2 +5.0
2.56– 3.15	0.7 1.9	+0.7 0	+1.9 +1.4	1.0 2.9	+1.2 0	+2.9 +2.2	1.8 3.7	+1.2 0	+3.7 +3.0	2.8 4.7	+1.2 0	+4.7 +4.0	4.2 7.2	+1.8 0	+7.2 +6.0
3.15– 3.94	0.9 2.4	+0.9 0	+2.4 +1.8	1.4 3.7	+1.4 0	+3.7 +2.8	2.1 4.4	+1.4 0	+4.4 +3.5	3.6 5.9	+1.4 0	+5.9 +5.0	4.8 8.4	+2.2 0	+8.4 +7.0
3.94– 4.73	1.1 2.6	+0.9 0	+2.6 +2.0	1.6 3.9	+1.4 0	+3.9 +3.0	2.6 4.9	+1.4 0	+4.9 +4.0	4.6 6.9	+1.4 0	+6.9 +6.0	5.8 9.4	+2.2 0	+9.4 +8.0

Tolerance Analysis for tool inserts and tool holders

Fit Chosen: LC *Locational clearance fits* are intended for parts which are normally stationary, but that can be freely assembled or disassembled. They range from snug fits for parts requiring accuracy of location, through the medium clearance fits for parts such as spigots, to the looser fastener fits where freedom of assembly is of prime importance.

Tool Holder (Hole): .5028/.5000

Tool Insert (Shaft): .4988/.4972

Table 6. American National Standard Clearance Locational Fits *ANSI B4.1-1967 (R1987)*

Nominal Size Range, Inches	Class LC 6			Class LC 7			Class LC 8			Class LC 9			Class LC 10			Class LC 11		
		Std. Tolerance Limits			Std. Tolerance Limits			Std. Tolerance Limits			Std. Tolerance Limits			Std. Tolerance Limits			Std. Tolerance Limits	
Over To	Clearance[a]	Hole H9	Shaft f8	Clearance[a]	Hole H10	Shaft e9	Clearance[a]	Hole H10	Shaft d9	Clearance[a]	Hole H11	Shaft c10	Clearance[a]	Hole H12	Shaft	Clearance[a]	Hole H13	Shaft
	Values shown below are in thousandths of an inch																	
0 – 0.12	0.3 1.9	+1.0 0	−0.3 −0.9	0.6 3.2	+1.6 0	− 0.6 − 1.6	1.0 2.0	+1.6 0	− 1.0 − 2.0	2.5 6.6	+2.5 0	− 2.5 − 4.1	4 12	+4 0	− 4 − 8	5 17	+6 0	− 5 − 11
0.12 – 0.24	0.4 2.3	+1.2 0	−0.4 −1.1	0.8 3.8	+1.8 0	− 0.8 − 2.0	1.2 4.2	+1.8 0	− 1.2 − 2.4	2.8 7.6	+3.0 0	− 2.8 − 4.6	4.5 14.5	+5 0	− 4.5 − 9.5	6 20	+7 0	− 6 −13
0.24 – 0.40	0.5 2.8	+1.4 0	−0.5 −1.4	1.0 4.6	+2.2 0	− 1.0 − 2.4	1.6 5.2	+2.2 0	− 1.6 − 3.0	3.0 8.7	+3.5 0	− 3.0 − 5.2	5 17	+6 0	− 5 −11	7 25	+9 0	− 7 −16
0.40 – 0.71	0.6 3.2	+1.6 0	−0.6 −1.7	1.2 5.6	+2.8 0	− 1.2 − 2.8	2.0 6.4	+2.8 0	− 2.0 − 3.6	3.5 10.3	+4.0 0	− 3.5 − 6.3	6 20	+7 0	− 6 −13	8 28	+10 0	− 8 −18
0.71 – 1.19	0.8 4.0	+2.0 0	−0.8 −2.0	1.6 7.1	+3.5 0	− 1.6 − 3.6	2.5 8.0	+3.5 0	− 2.5 − 4.5	4.5 13.0	+5.0 0	− 4.5 − 8.0	7 23	+8 0	− 7 −15	10 34	+12 0	−10 −22
1.19 – 1.97	1.0 5.1	+2.5 0	−1.0 −2.6	2.0 8.5	+4.0 0	− 2.0 − 4.5	3.6 9.5	+4.0 0	− 3.0 − 5.5	5.0 15.0	+6 0	− 5.0 − 9.0	8 28	+10 0	− 8 −18	12 44	+16 0	−12 −28
1.97 – 3.15	1.2 6.0	+3.0 0	−1.0 −3.0	2.5 10.0	+4.5 0	− 2.5 − 5.5	4.0 11.5	+4.5 0	− 4.0 − 7.0	6.0 17.5	+7 0	− 6.0 −10.5	10 34	+12 0	−10 −22	14 50	+18 0	−14 −32
3.15 – 4.73	1.4 7.1	+3.5 0	−1.4 −3.6	3.0 11.5	+5.0 0	− 3.0 − 6.5	5.0 13.5	+5.0 0	− 5.0 − 8.5	7 21	+9 0	− 7 −12	11 39	+14 0	−11 −25	16 60	+22 0	−16 −38
4.73 – 7.09	1.6 8.1	+4.0 0	−1.6 −4.1	3.5 13.5	+6.0 0	− 3.5 − 7.5	6 16	+6 0	− 6 −10	8 24	+10 0	− 8 −14	12 44	+16 0	−12 −28	18 68	+25 0	−18 −43
7.09 – 9.85	2.0 9.3	+4.5 0	−2.0 −4.8	4.0 15.5	+7.0 0	− 4.0 − 8.5	7 18.5	+7 0	− 7 −11.5	10 29	+12 0	−10 −17	16 52	+18 0	−16 −34	22 78	+28 0	−22 −50
9.85 – 12.41	2.2 10.2	+5.0 0	−2.2 −5.2	4.5 17.5	+8.0 0	− 4.5 − 9.5	7 20	+8 0	− 7 −12	12 32	+12 0	−12 −20	20 60	+20 0	−20 −40	28 88	+30 0	−28 −58
12.41 – 15.75	2.5 12.0	+6.0 0	−2.5 −6.0	5.0 20.0	+9.0 0	− 5 −11	8 23	+9 0	− 8 −14	14 37	+14 0	−14 −23	22 66	+22 0	−22 −44	30 100	+35 0	−30 −65
15.75 – 19.69	2.8 12.8	+6.0 0	−2.8 −6.8	5.0 21.0	+10.0 0	− 5 −11	9 25	+10 0	− 9 −15	16 42	+16 0	−16 −26	25 75	+25 0	−25 −50	35 115	+40 0	−35 −75

Tolerance limits given in body of table are added or subtracted to basic size (as indicated by + or – sign) to obtain maximum and minimum sizes of mating parts.

All data above heavy lines are in accordance with American-British-Canadian (ABC) agreements. Symbols H6, H7, s6, etc. are hole and shaft designations in ABC system. Limits for sizes above 19.69 inches are not covered by ABC agreements but are given in the ANSI Standard.

Tolerance Analysis for Punch and die clearance

Punch: .248/.249

Die: .250/.251

Backcut punch to 3/16" dia to provide clearance through die.

Tolerances determined from reverse engineering existing hole punch designs.

Shear stress pin

Shear Stress Equation Single Shear

Shear Stress Average = Applied Force / Area

or

Shear Stress ave.= $F/(\pi r^2)$

or

Shear Stress ave.= $4F/(\pi d^2)$

Where:

Shear Stress ave = (N/mm^2, lbs/in^2)

F = Applied Force (N, Lbs)

π = pi or (3.14157)

r = Radius (mm, in.)

d = Diameter (mm, in.)

Bolt or Pin Single Shear Stress	
Applied Force F (N, lbs) =	30.00
Bolt/Pin Diameter d (mm, in) =	0.25
Plate Thickness t (mm, in) =	0.19
Ultimate (Yield Min.) Stress (N/mm^2, lbs/in^2) =	45000.00
Factor of Safety =	3.00
Results	
Area of Bolt/Pin (mm^2, in^2) =	0.049
Shear Stress ave Bolt/Pin (N/mm^2, lbs/in^2) =	611.16
Bearing Area Stess (N/mm^2, lbs/in^2) =	631.58
allowable stress (N/mm^2, lbs/in^2) =	15000.00

This shows the analysis for the shear stress on our pin. The ultimate yield stress of 1045 steel was found to be about 45,000 psi. I used an applied force of 30 lbs which greatly exceeds the necessary grip force calculated to use for our application. We see that our allowable stress is 15,000 psi and that the shear stress on the pin is nowhere near this level. We are able to conclude that the size of our pin and the material selected will be more than strong enough to withstand the forces applied during use.

Grip force

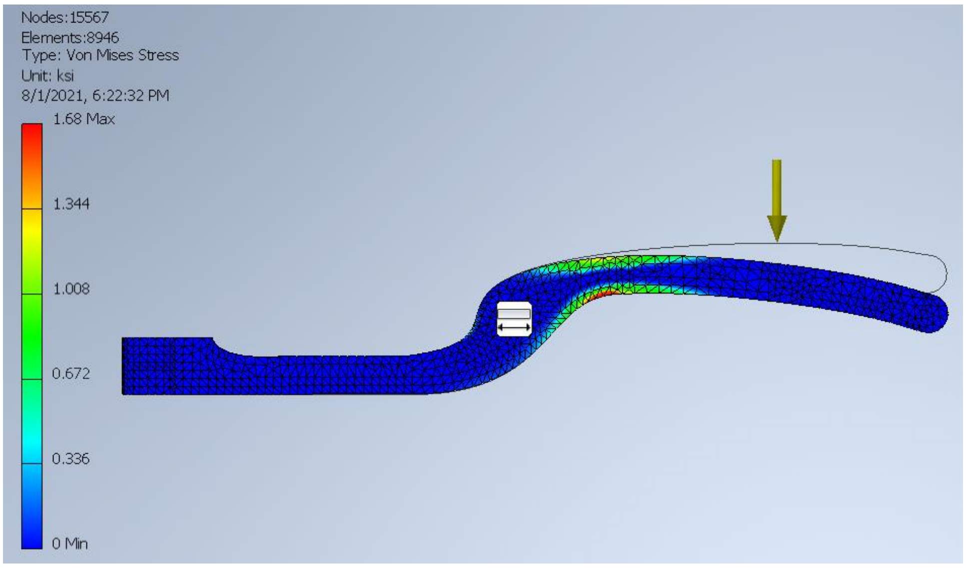
Punch Force = Perimeter(in) x Material Thickness (in) x Shear Strength (psi)

Grip Force Calculation			
Parameter	Value	Units	
Punch Hole Diameter	0.25	in	
Total Paper Thickness	0.025	in	
Paper Strength	40	psi	
Punch Reach	4.25	in	
Handle Length	4.25	in	
Punch Force	0.785	lbs	C4*PI()*C5*C6
Grip Force	0.785	lbs	(C7*C9)/C8

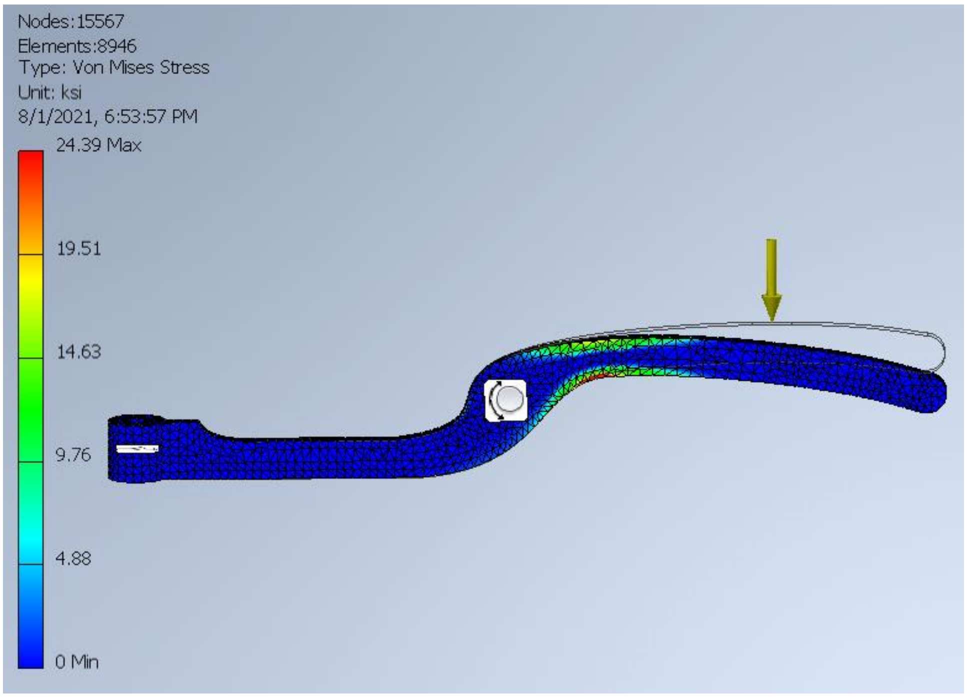
The above image shows calculations for necessary grip force required to punch through 5 sheets of paper. The force comes out to be 0.785 lbs which is easily produced by the average person. This analysis shows there is very low risk that our design will require too much force to punch through 5 sheets of paper because even if the calculations are not totally accurate and our calculations are off by a factor of 10 (which is unlikely) 7.85 lbs of force is still easily produced by a person using this design.

FEA Analysis of hole punch handle

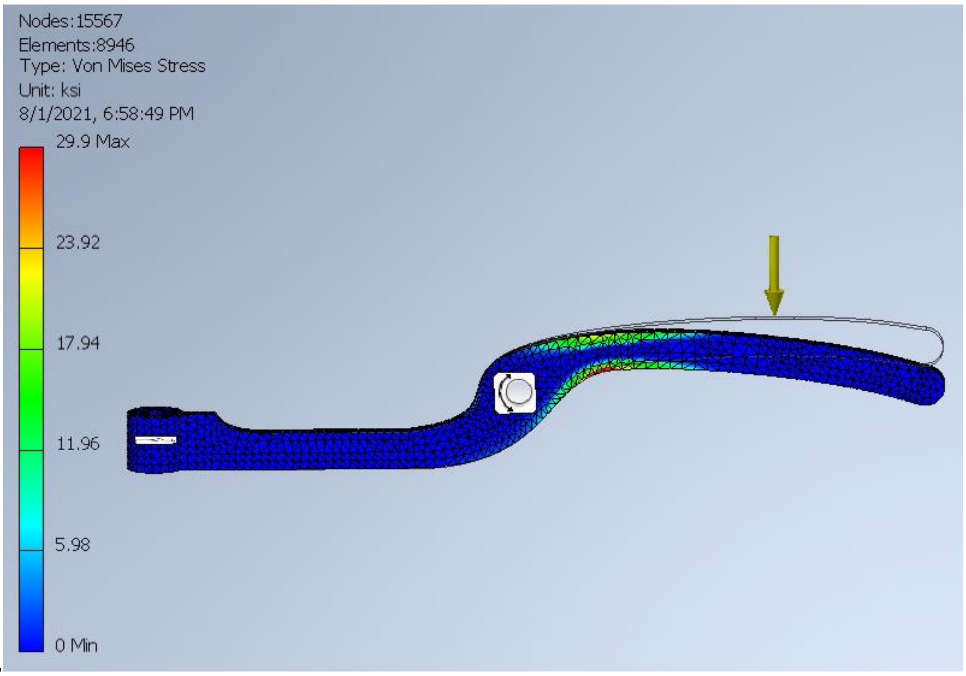
Part Filename: 4110-00-001.ipt
Program: Autodesk Inventor
Date: 8/1/21
Goal: Determine force that will cause the handle to start to yield.
Results: Handle will start to yield at approximately 90 lbs of force.



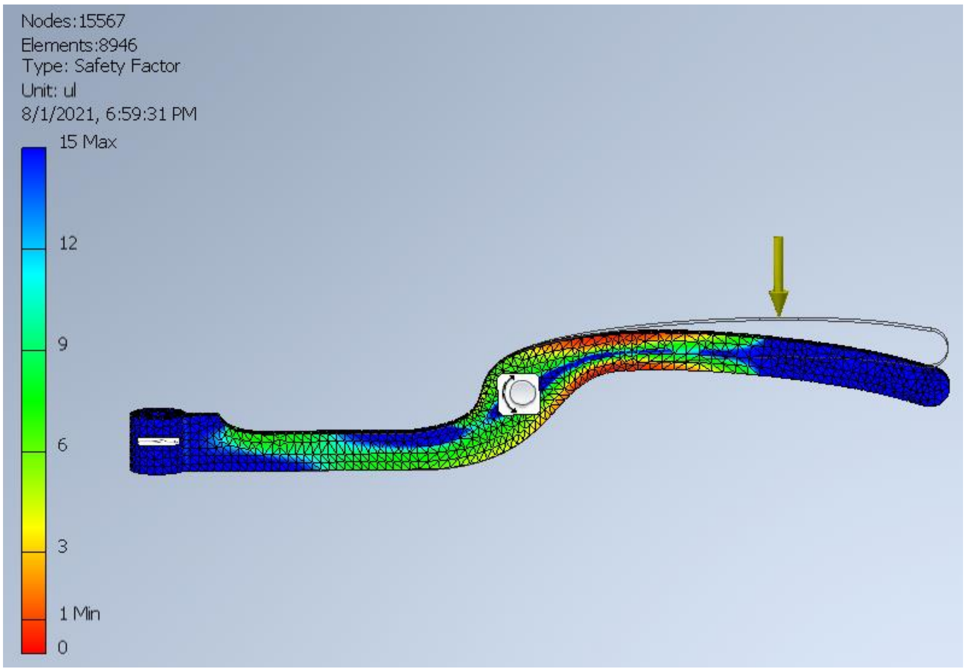
The above image shows analysis of 5lbs of force on the handle of the hole punch resulting in a max localized stress of 1680 psi. This is much lower than the yield strength of the material which is 30 ksi.



The above image shows analysis of 72lbs of force on the handle of the hole punch resulting in a max localized stress of 24390 psi. This is still below the yield strength of our material.



The above image shows analysis of 89lbs of force on the handle of the hole punch resulting in a max localized stress of 29900 psi which is right at the yield strength of our material.



We can also take a look at the safety factor to see if we are showing any deformation of material. Our minimum safety factor is right at 1 which means anything above 89 lbs of force will bring the safety factor below 1 and begin to deform our handle.

5.1.4 Methodology

Tolerance Analysis for the pin and the pin hole

This analysis was performed looking up the necessary tolerances in Table 9, *ANSI Standard Force and Shrink Fits* in the machinery handbook. No experimentation was necessary for this analysis. Computation was also not necessary for this part of the engineering analysis.

Tolerance Analysis for tool inserts and tool holders

This analysis was performed by looking up the necessary tolerances in Table 6, *American National Standard Clearance Locational Fits* in the machinery handbook. No experimentation or computation was necessary for this analysis.

Tolerance Analysis for Punch and die clearance

This analysis was performed by reverse engineering existing hole punch designs and determining clearances from them. No experimentation was necessary for this analysis as it was pretty straightforward and easy to look at what has worked in previous designs to determine what would work for our design.

Shear stress pin

This analysis was performed using a shear stress equation with the known information about the dimensions of our pin and thickness of our handles that will apply the force causing the shear stresses on the pin. A simple shear stress equation was used to calculate how much stress the pin will be under when a rather high force of 30 lbs is applied. No experimentation was necessary for this analysis.

Grip Force

This analysis was performed by calculating the grip force required to punch through 5 standard sheets of paper. A punch force equation was used with the perimeter of the hole, the thickness of the paper, and the strength of the paper. Using this equation, we determined how much force is necessary to punch through 5 sheets of paper. No experimentation was necessary for this analysis.

FEA Analysis of hole punch handle

This analysis was performed using finite element analysis on Solidworks. Our model of our hole punch handle was tested in the program to determine the force required to make the handle yield.

5.1.5 Results

Tolerance Analysis for the pin and the pin hole

Fit Chosen: FN 2 *Medium drive fits* are suitable for ordinary steel parts, or for shrink fits on light sections.They are about the tightest fits that can be used with high-grade cast-iron external members.

Hole: .2506/.2500

Pin (Shaft): .2514/.2510

Tolerance Analysis for tool inserts and tool holders

Fit Chosen: LC *Locational clearance fits* are intended for parts which are normally stationary, but that can be freely assembled or disassembled. They range from snug fits for parts requiring accuracy of location, through the medium clearance fits for parts such as spigots, to the looser fastener fits where freedom of assembly is of prime importance.

Tool Holder (Hole): .5028/.5000

Tool Insert (Shaft): .4988/.4972

Tolerance Analysis for Punch and die clearance

Punch: .248/.249

Die: .250/.251

Back cut punch to 3/16" dia to provide clearance through die.

Tolerances determined from reverse engineering existing hole punch designs.

With a maximum allowable stress of 15,000 psi using a factor of safety value of 3, our pin is easily strong enough to withstand the stresses it will be subjected to during the design's intended application.

The goal of this analysis was to determine if the average person would be able to apply the grip force necessary to punch through 5 standard sheets of paper. After these calculations were made, we found the required punch force necessary to punch through 5 sheets of paper is only around 1 lb. This is easily attainable by the average person.

The finite element analysis performed in Solidworks showed that our handle will begin to yield when about 90 lbs of grip force is applied. Most people are not capable of applying a grip force this high, and this force is also much greater than the force necessary for our design to achieve its goal of punching through 5 sheets of paper. We can conclude that our handle dimensions and material will work for our design's intended application.

5.1.6 Significance

Tolerance Analysis for the pin and the pin hole

The diameter of the shaft of the pin will be changed from 0.25” to 0.2514”/0.2510”. This changed because of the information found in the table about medium drive fits. This change is made so that the pin will fit tightly in the hole.

Tolerance Analysis for tool inserts and tool holders

A locational clearance fit was chosen after referring to the Machinery's Handbook. This will allow assembly of the tool insert into the tool holder and still provide good location between the mating punch and die tools.

Tolerance Analysis for Punch and die clearance

Reverse engineering several new and used hole punches provided punch and die clearances that could be applied to our design. This also provided us with the idea to back cut the punch to provide extra clearance when the punch goes through the die.

Shear stress pin

After completing this analysis, it just confirmed that the material for the pin that was selected will work. No design changes necessary from this analysis.

Grip force

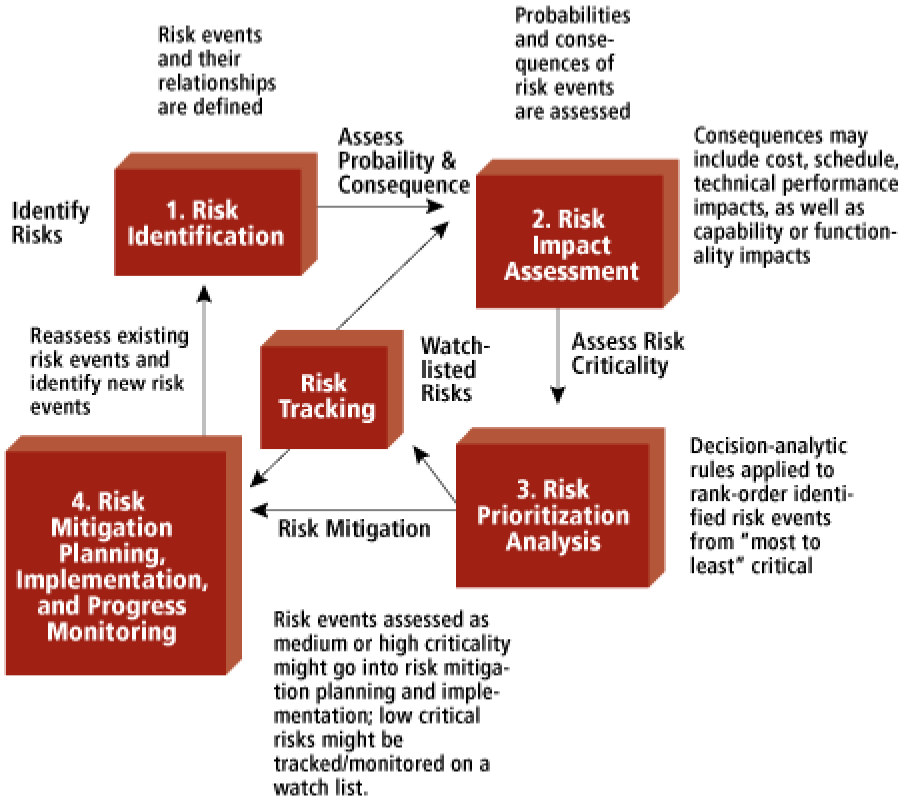
This analysis confirmed that our design will not need an unrealistic grip force applied in order for it to work. No design changes necessary from this analysis.

FEA Analysis of hole punch handle

Our FEA analysis showed that it would take approximately 90 lbs to deform the handle. This is far above the calculated force required to punch through 5 sheets of paper. No design changes needed from this analysis.

6 RISK ASSESSMENT

* For context review source: http://www.mitre.org/publications/systems-engineering-guide/acquisition-systems-engineering/risk-management



18. RISK IDENTIFICATION

* For context review source: http://www.mitre.org/publications/systems-engineering-guide/acquisition-systems-engineering/risk-management/risk-identification)

19. RISK ANALYSIS

* This is based on your project engineering analysis. Tools include simulation, happiness equations, calculation by hand or with SolidWorks, MATLAB, etc. Discuss risk as it pertains to your performance specification, cost, and schedule.

http://www.mitre.org/publications/systems-engineering-guide/acquisition-systems-engineering/risk-management/risk-management-tools

20. RISK PRIORITIZATION

*Write a short description of how your team prioritized risk for your project. Include any tables or diagrams that support your prioritization

http://www.mitre.org/publications/systems-engineering-guide/acquisition-systems-engineering/risk-management/risk-impact-assessment-and-prioritization

7 CODES AND STANDARDS

21. IDENTIFICATION

Paper Material Properties:

ASTM D828 -16e1 https://www.astm.org/Standards/D828.htm
ISO 1924-2 https://www.iso.org/standard/41397.html

Standard Hole Size of hole punch:

International Standard: ISO 838
US Standard: The diameter of the holes varies between manufacturers, with typical values being 1⁄4 to 5⁄16 inch (6 to 8 mm). The 5⁄16 value is most commonly used, as it allows for looser tolerances in both ring binder and paper punching.

22. JUSTIFICATION

The above standards relate to hole punches and paper properties. The paper standards specify material properties for standard types of paper. These properties will calculate the forces required to punch holes into paper. The hole punch standard specifies standard sizes and tolerances of holes punches.

23. DESIGN CONSTRAINTS

These standards constrain our punch size to a certain diameter if the tool is to be used as a standard hole punch. The material properties of paper will dictate the size of the hole punch and how long the handles will need to be to provide the proper amount of force at the punch to punch through the paper.

7.1.1 Safety

1. The grip force required to punch through a standard sheet of paper must not be too high that it could potentially injure the user when they are attempting to use our design.

24. SIGNIFICANCE

Our prototype will be made with a standard ¼" punch size. The ratio between the hole punch reach and the handles will be kept close to 1:1.

8 WORKING PROTOTYPE

25. PROTOTYPE PHOTOS

26. WORKING PROTOTYPE VIDEO

JME 4110 Hole punch Prototype

2. HTTPS://YOUTU.BE/SAPZAJ7R92Y

1. PROTOTYPE COMPONENTS

3.

The die is on the left and the punch is on the right. These slip into the insert holders. The insert holders were fitted for alignment and welded to the handles. These inserts are clocked with a flat area. #6-32 screws thread into the insert holders and bear done onto the inserts to keep them in place.

4. 

The torsion spring is shown here. It is retained by the rubber hose that is used for handle grips. These grips make the tool more comfortable to use. The spring helps hold the tool open and releases the tool after punching a hole.

5.

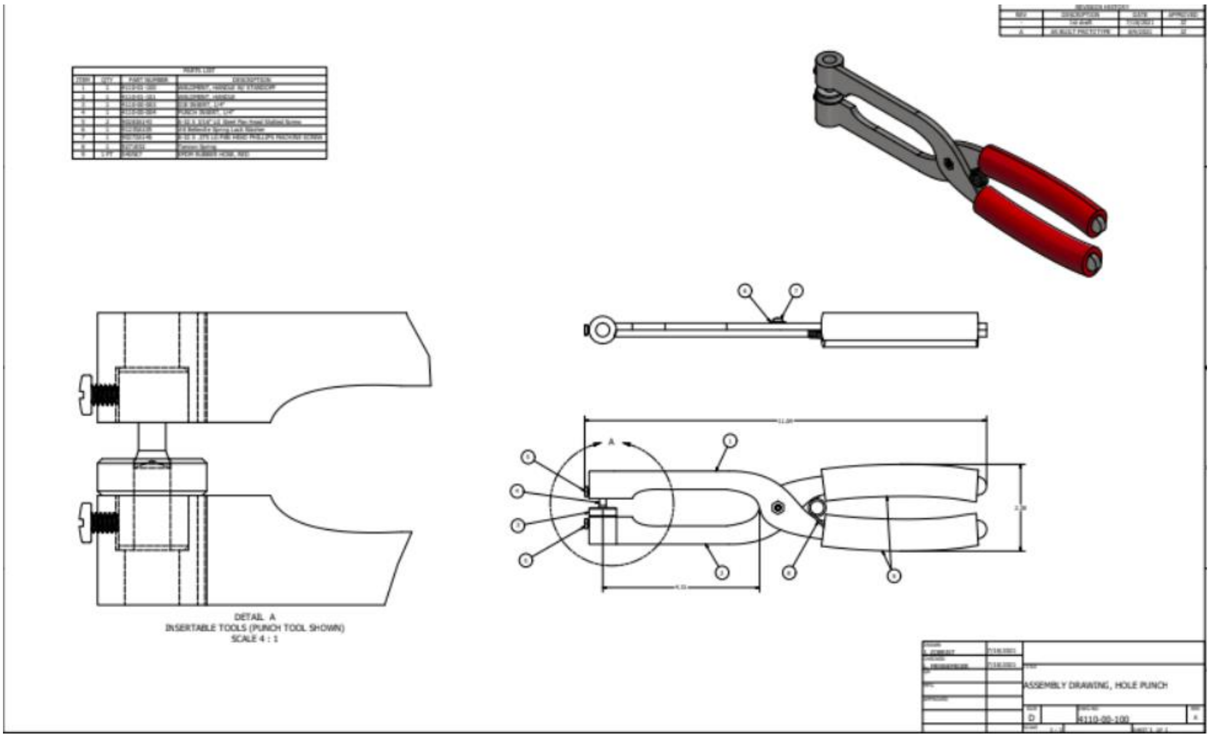
The screw is shown that holds the handles together. One handle has a press-fit threaded standoff. The other handle has a close-fit hole that slips over the standoff. The standoff is slightly taller than the thickness of the handles. A Bellville spring washer was added to add some preload to the joint. This gives the handles a tighter feel.

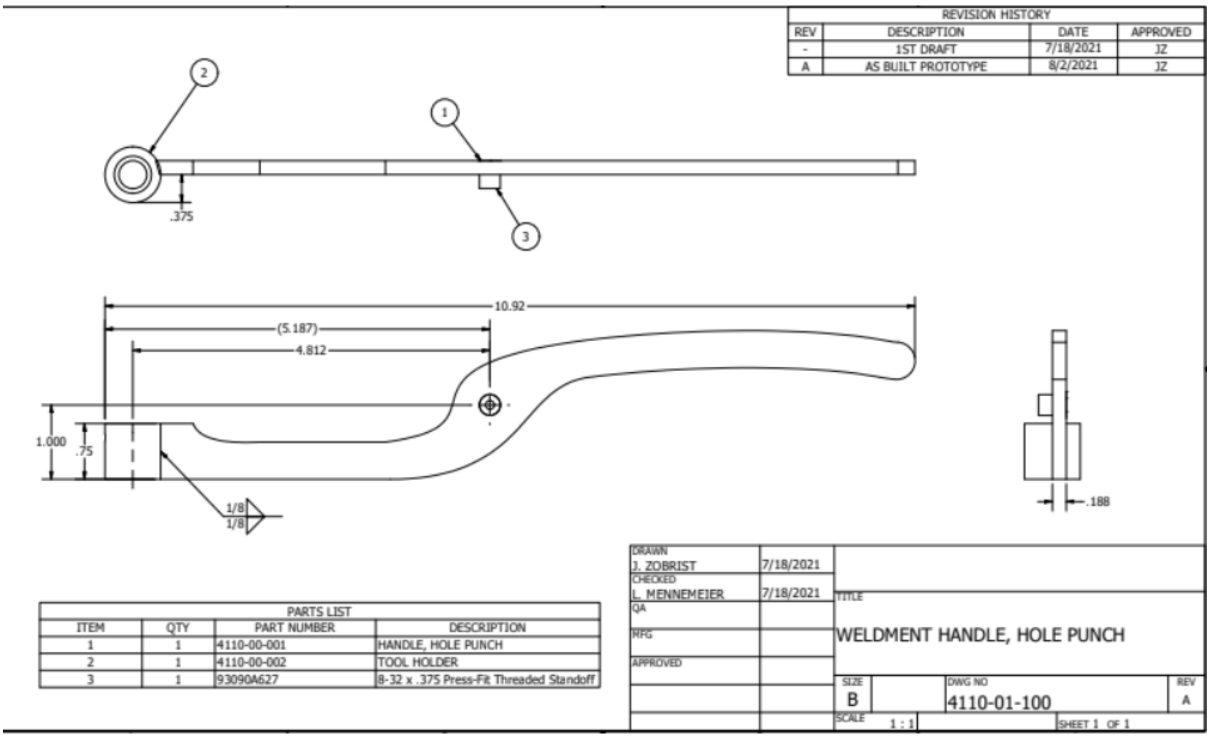
This shows the press-fit standoff that is pressed into one of the handles. The hex portion of the standoff deforms the material of the handle and prevents the standoff from twisting out of the handle.

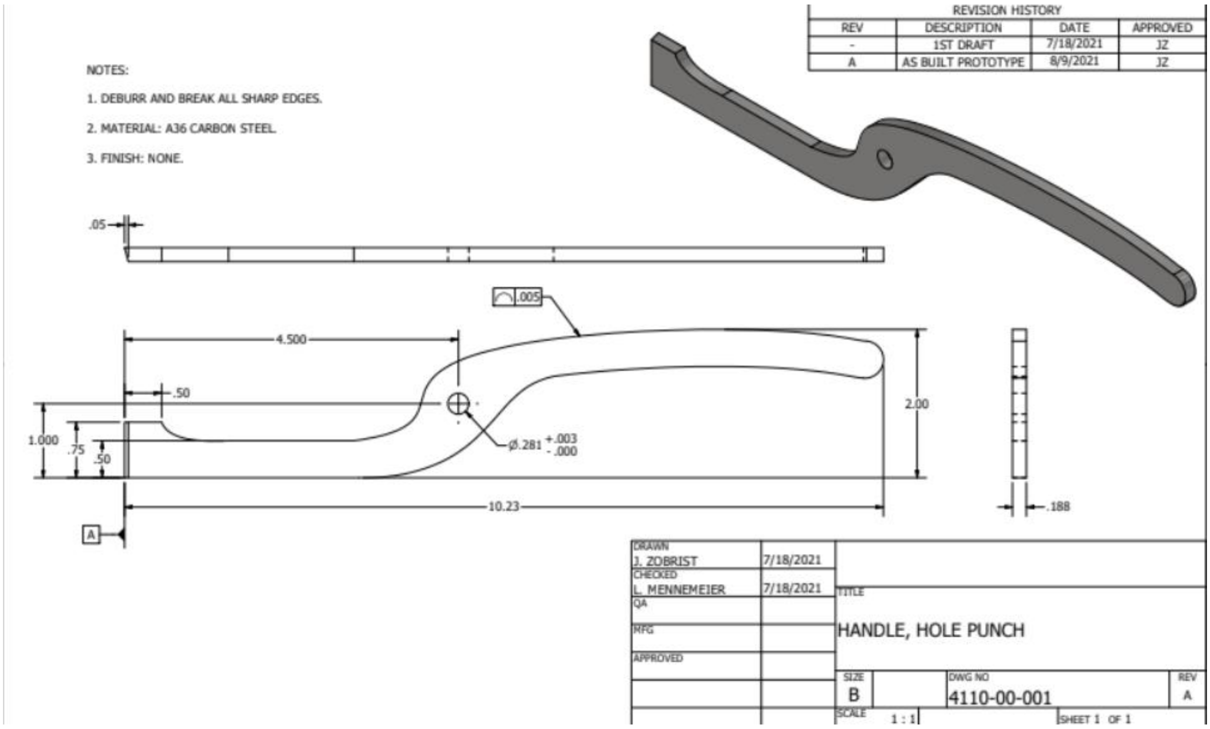
9 DESIGN DOCUMENTATION

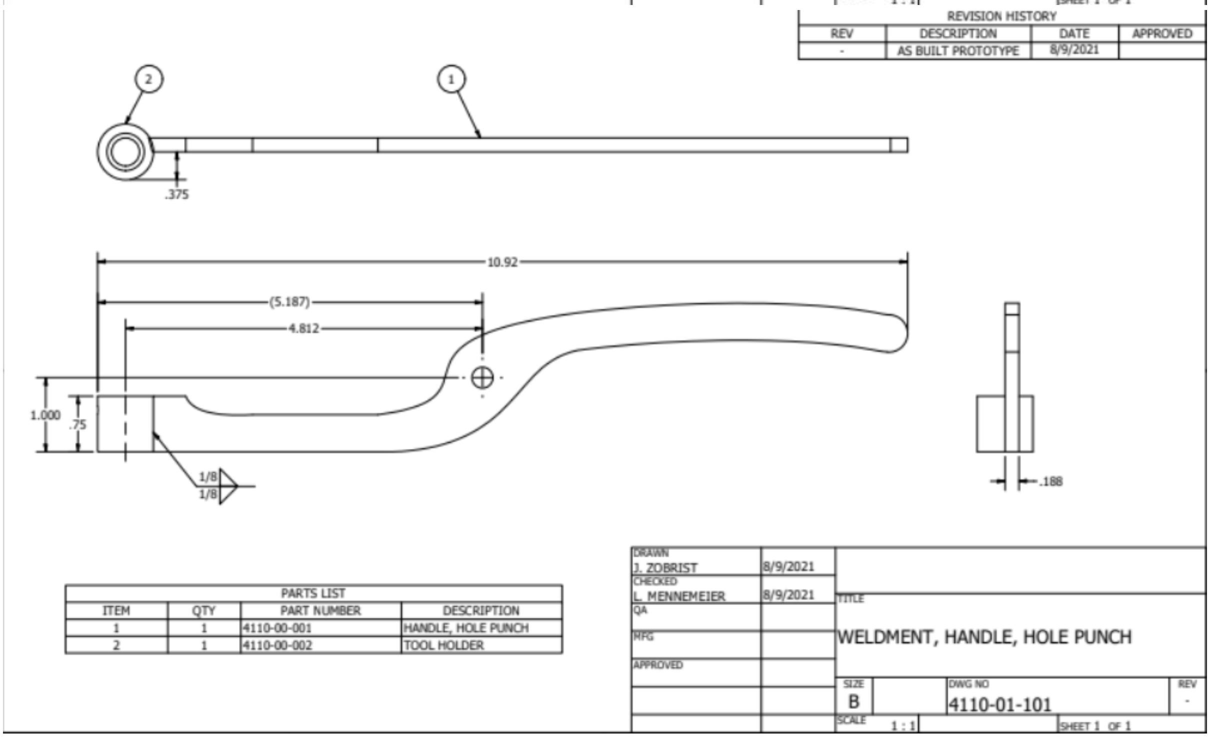
1. FINAL DRAWINGS AND DOCUMENTATION

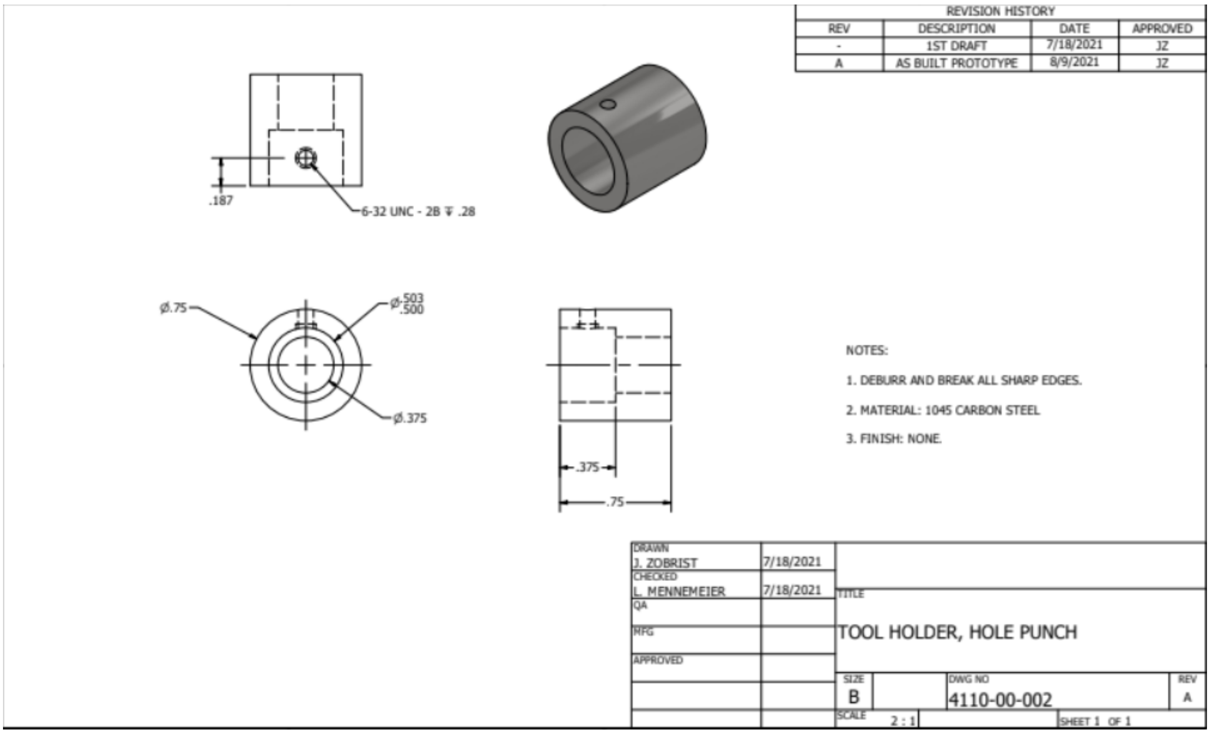
9.1.1 Engineering Drawings



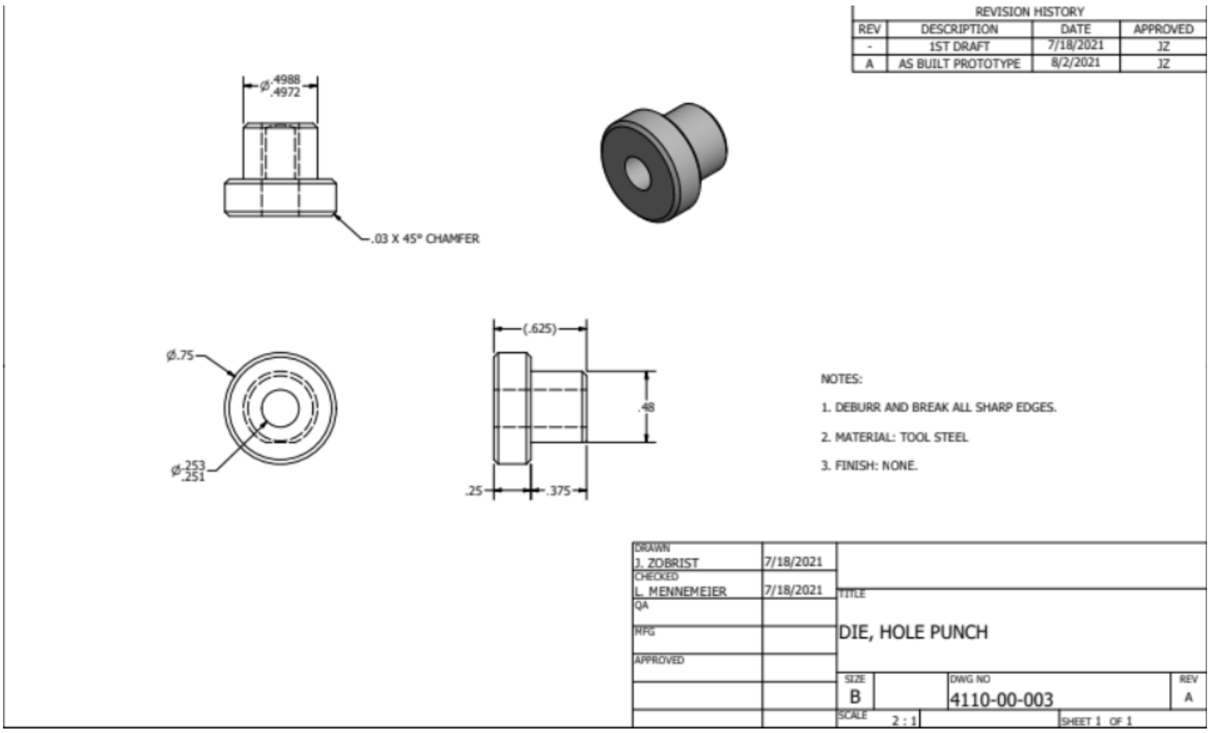



REVISION HISTORY
REV | DESCRIPTION | DATE | APPROVED
- | 1ST DRAFT | 7/18/2021 | JZ
A | AS BUILT PROTOTYPE | 8/9/2021 | JZ
NOTES:
1. DEBURR AND BREAK ALL SHARP EDGES.
2. MATERIAL: A36 CARBON STEEL.
3. FINISH: NONE.
.05
.005
4.500
.50
2.00
1.000
.75
.50
Ø.281 +.003 -.000
10.23
.188
A
DRAWN J. ZOBRIST 7/18/2021
CHECKED L. MENNEMEIER 7/18/2021
QA
MFG
APPROVED
TITLE HANDLE, HOLE PUNCH
SIZE B
DWG NO 4110-00-001
REV A
SCALE 1 : 1
SHEET 1 OF 1

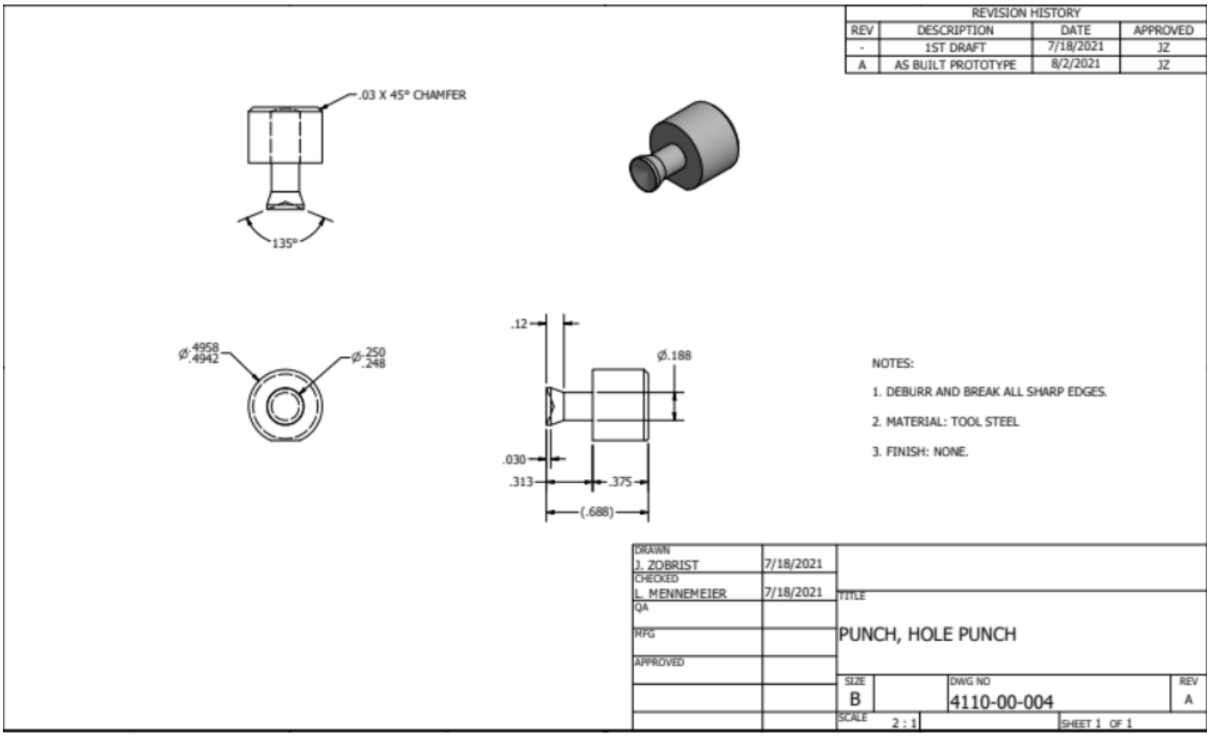

REVISION HISTORY
REV | DESCRIPTION | DATE | APPROVED
- | AS BUILT PROTOTYPE | 8/9/2021 |
2
1
.375
10.92
(5.187)
4.812
1.000
.75
1/8
1/8
.188
PARTS LIST
ITEM | QTY | PART NUMBER | DESCRIPTION
1 | 1 | 4110-00-001 | HANDLE, HOLE PUNCH
2 | 1 | 4110-00-002 | TOOL HOLDER
DRAWN J. ZOBRIST 8/9/2021
CHECKED L. MENNEMEIER 8/9/2021
QA
MFG
APPROVED
TITLE WELDMENT, HANDLE, HOLE PUNCH
SIZE B
DWG NO 4110-01-101
REV -
SCALE 1 : 1
SHEET 1 OF 1



REVISION HISTORY
REV | DESCRIPTION | DATE | APPROVED
- | 1ST DRAFT | 7/18/2021 | JZ
A | AS BUILT PROTOTYPE | 8/9/2021 | JZ
.187
6-32 UNC - 2B ↧ .28
Ø.75
Ø.503 .500
Ø.375
.375
.75
NOTES:
1. DEBURR AND BREAK ALL SHARP EDGES.
2. MATERIAL: 1045 CARBON STEEL
3. FINISH: NONE.
DRAWN
J. ZOBRIST 7/18/2021
CHECKED
L. MENNEMEIER 7/18/2021
QA
MFG
APPROVED
TITLE
TOOL HOLDER, HOLE PUNCH
SIZE B
DWG NO 4110-00-002
REV A
SCALE 2 : 1
SHEET 1 OF 1



REVISION HISTORY
REV | DESCRIPTION | DATE | APPROVED
- | 1ST DRAFT | 7/18/2021 | JZ
A | AS BUILT PROTOTYPE | 8/2/2021 | JZ
Ø.4988 .4972
.03 X 45° CHAMFER
Ø.75
Ø.253 .251
(.625)
.48
.25
.375
NOTES:
1. DEBURR AND BREAK ALL SHARP EDGES.
2. MATERIAL: TOOL STEEL
3. FINISH: NONE.
DRAWN
J. ZOBRIST 7/18/2021
CHECKED
L. MENNEMEIER 7/18/2021
QA
MFG
APPROVED
TITLE
DIE, HOLE PUNCH
SIZE B
DWG NO 4110-00-003
REV A
SCALE 2 : 1
SHEET 1 OF 1



9.1.2 Sourcing instructions

Hole Punch 4110-00-100

PRODUCT NAME	Hole Punch	CONTACT INFO
APPROVED BY	J. Zobrist	
APPROVAL DATE	Monday, August 10, 0201	
PART COUNT	15	
TOTAL COST	$ 19.43	

ITEM NUMBER	PART NAME	DESCRIPTION	QUANTITY	UNITS	CATEGORY	ASSEMBLY PHASE	SOURCE / SUPPLIER	LINK TO SUPPORTING DOC	UNIT COST	TOTAL PART COST
1	4110-01-100	WELDMENT, HANDLE W/ STANDOFF	1	EA	Manufacture, Weldment	Sub-Assembly	Team Hole Punch	4110-01-100 Drawing	$ -	$ -
0.1	4110-00-001	HANDLE	1	EA	Manufacture, CNC Plasma Cut	Part	Raw Material: Shapiro Metal Supply	Shapiro, 3/16" A36 Steel	$ 6.50	$ 6.50
0.2	4110-00-002	TOOL HOLDER	1	EA	Manufacture, Lathe	Part	Raw Material: McMaster	McMaster 1045 Rod	$ 0.75	$ 0.75
0.3	93090A627	8-32 x .375 Press-Fit Threaded Standoff	1	EA	Purchase	Part	McMaster	McMaster 93090A627	$ 0.43	$ 0.43
2	4110-01-101	WELDMENT, HANDLE W/ STANDOFF	1	EA	Manufacture, Weldment	Sub-Assembly	Team Hole Punch	4110-01-101 Drawing	$ -	$ -
0.1	4110-00-001	HANDLE	1	EA	Manufacture, CNC Plasma Cut	Part	Raw Material: Shapiro Metal Supply	Shapiro, 3/16" A36 Steel	$ 6.50	$ 6.50
0.2	4110-00-002	TOOL HOLDER	1	EA	Manufacture, Lathe	Part	Raw Material: McMaster	McMaster 1045 Rod	$ 0.75	$ 0.75
3	4110-00-003	DIE INSERT, 1/4"	1	EA	Manufacture, Lathe	Part	Raw Material: McMaster	McMaster A2 Tool Steel	$ 0.68	$ 0.68
4	4110-00-004	PUNCH INSERT, 1/4"	1	EA	Manufacture, Lathe	Part	Raw Material: McMaster	McMaster A2 Tool Steel	$ 0.75	$ 0.75
5	90283A143	6-32 X 3/16" LG Steel Pan Head Slotted Screw	2	EA	Purchase	Part	McMaster	McMaster 90283A143	$ 0.02	$ 0.05
6	91235A105	#8 Belleville Spring Lock Washer	1	EA	Purchase	Part	McMaster	McMaster 91235A105	$ 0.34	$ 0.34
7	90272A146	8-32 X .375 LG PAN HEAD PHILLIPS MACHINE SCREW	1	EA	Purchase	Part	McMaster	McMaster 90272A146	$ 0.02	$ 0.02
8	9271K52	Torsion Spring	1	EA	Purchase	Part	McMaster	McMaster 9271K52	$ 1.07	$ 1.07
9	5405K7	EPDM RUBBER HOSE, RED	1	FT	Purchase	Part	McMaster	McMaster 5405K7	$ 1.60	$ 1.60
			15						TOTAL	$ 19.43

7.2 FINAL PRESENTATION

https://youtu.be/E7AL0cXpZv0

8 TEARDOWN

9 APPENDIX A - PARTS LIST

Cost Estimate

Hole Punch

							Rip
Department: Project Management						Project Manager:	JZ
Division: Estimates						Date:	7/12/2021

No.	Item Description	Unit	Unit Cost	Qty.	Material	Labor	Total
1	Die Handle	ea	$39.00	0.25	Steel		$9.75
2	Punch Handle	ea	$39.00	0.25	Steel		$9.75
3	Die Material	ft	$13.06	0.042	Tool Steel		$0.55
4	Punch Material	ft	$3.35	0.083	Tool Steel		$0.28
5	Binding Pin	ea	$2.52	1	Steel		$2.52
6	Grips	ea	$8.99	1	Heatshrink Grip		$8.99

10 APPENDIX B - BILL OF MATERIALS

ITEM NUMBER	PART NAME	DESCRIPTION	QUANTITY	UNITS	CATEGORY	ASSEMBLY PHASE	SOURCE / SUPPLIER	LINK TO SUPPORTING DOC
1	4110-01-100	WELDMENT, HANDLE W/ STANDOFF	1	EA	Manufacture, Weldment	Sub-Assembly	Team Hole Punch	4110-01-100 Drawing
0.1	4110-00-001	HANDLE	1	EA	Manufacture, CNC Plasma Cut	Part	Raw Material: Shapiro Metal Supply	Shapiro, 3/16" A36 Steel
0.2	4110-00-002	TOOL HOLDER	1	EA	Manufacture, Lathe	Part	Raw Material: McMaster	McMaster 1045 Rod
0.3	93090A627	8-32 x .375 Press-Fit Threaded Standoff	1	EA	Purchase	Part	McMaster	McMaster 93090A627
2	4110-01-101	WELDMENT, HANDLE W/ STANDOFF	1	EA	Manufacture, Weldment	Sub-Assembly	Team Hole Punch	4110-01-101 Drawing
0.1	4110-00-001	HANDLE	1	EA	Manufacture, CNC Plasma Cut	Part	Raw Material: Shapiro Metal Supply	Shapiro, 3/16" A36 Steel
0.2	4110-00-002	TOOL HOLDER	1	EA	Manufacture, Lathe	Part	Raw Material: McMaster	McMaster 1045 Rod
3	4110-00-003	DIE INSERT, 1/4"	1	EA	Manufacture, Lathe	Part	Raw Material: McMaster	McMaster A2 Tool Steel

4	4110-00-004	PUNCH INSERT, 1/4"	1	EA	Manufacture, Lathe	Part	Raw Material: McMaster	McMaster A2 Tool Steel
5	90283A143	6-32 X 3/16" LG Steel Pan Head Slotted Screw	2	EA	Purchase	Part	McMaster	McMaster 90283A143
6	91235A105	#8 Belleville Spring Lock Washer	1	EA	Purchase	Part	McMaster	McMaster 91235A105
7	90272A146	8-32 X .375 LG PAN HEAD PHILLIPS MACHINE SCREW	1	EA	Purchase	Part	McMaster	McMaster 90272A146
8	9271K52	Torsion Spring	1	EA	Purchase	Part	McMaster	McMaster 9271K52
9	5405K7	EPDM RUBBER HOSE, RED	1	FT	Purchase	Part	McMaster	McMaster 5405K7

11 APPENDIX C – COMPLETE LIST OF ENGINEERING DRAWINGS

12 ANNOTATED BIBLIOGRAPHY